WRF idealized-roughness response: PBL scheme and resolution dependence

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WRF idealized-roughness response:

PBL scheme and resolution dependence

towards parameterization-aware WRF application …

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with data from Jake Badger

partial support from X-WiWa and the New European Wind Atlas projects

for NEWA (Dec.2016),
modified from EMS conf.(Trieste 9/2016)

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Rough motivation... PBL-schemes and z_0

- WRF sensitivity to surface conditions:
  - **PBL-scheme** response
  - **Resolution** dependence
  - Reynolds-number dependence (?)

- Background roughness length (z_0) crucial for e.g.
  - Wind-field generalization (meso- → micro-scale)
  - Surface-layer applications needing surface-fluxes

- Current generalization :
  - Find domain-scale forcing of micro-scale model
    - Need z_0 (forcing via e.g. geostrophic drag-law)
  - (+small perturbations due to Δz_0, Δz_{sfc})

Ideal WRF simulations: setup

- ”Open” horizontal boundary conditions (zero gradients)
- 200*100*(40 or 80) domain
  - x: 100 Water cells and 100 land cells

- input z_0 : between ~0.1mm(Charnock), 10cm over land

- $\langle w'\theta' \rangle_{\mathrm{sfc}} = 0$
- Geostrophic Wind: constant with z
  - → neutral wind speed profile in PBL (at least up to $h/2$)
- Inversion height: h~650m

- 4-day simulations with 10-min. output

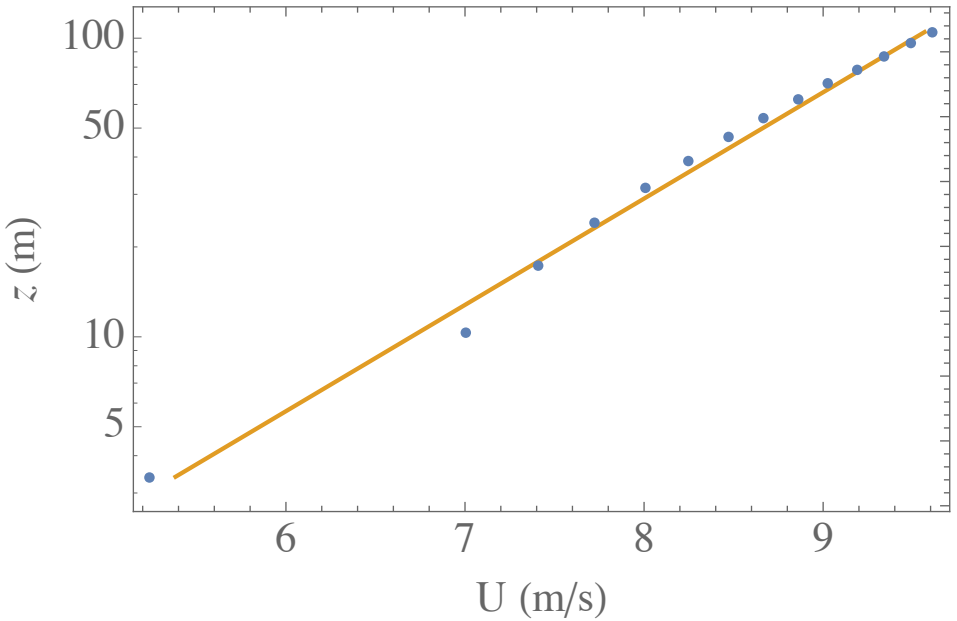
Mesoscale-models' interaction with 'bottom'

- Calculating effective roughness length
  - Bottom 2 levels:

$$\alpha = \frac{dU/dz}{U/z} = \frac{1}{\ln\left(z/z_{0,\mathrm{eff}}\right)} \quad \rightarrow \quad z_{0,\mathrm{eff}} = \frac{z_1+z_2}{2}\exp\left[-\frac{(U_1+U_2)}{(z_1+z_2)}\frac{(z_2-z_1)}{(U_2-U_1)}\right]$$

  - Fit profile to $\ln\left(z/z_{0,\mathrm{eff}}\right)$

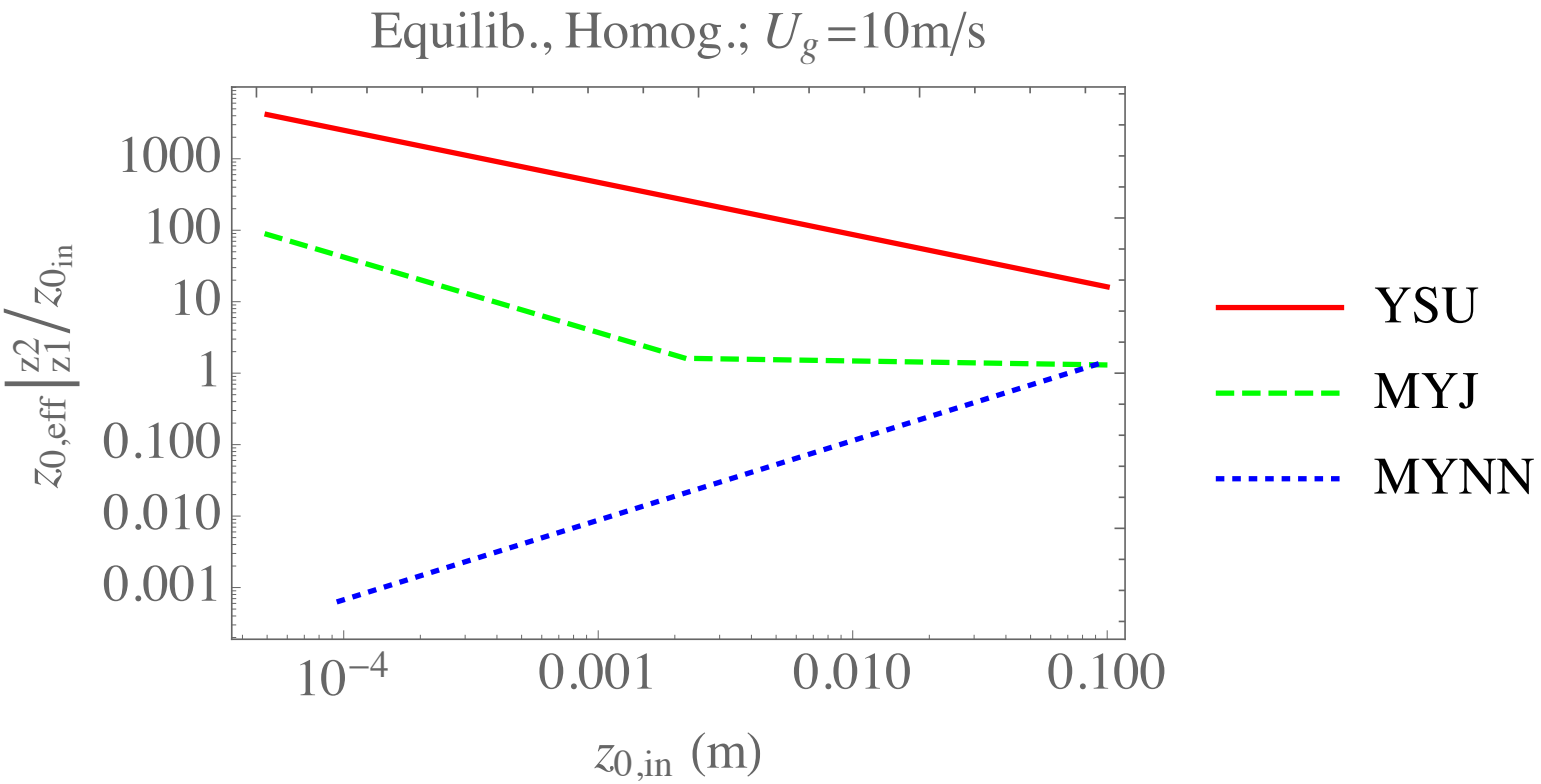
YSU example:



Equilibrium z_0-response : from bottom-2 levels

(homogeneous domains, G=10 m/s)

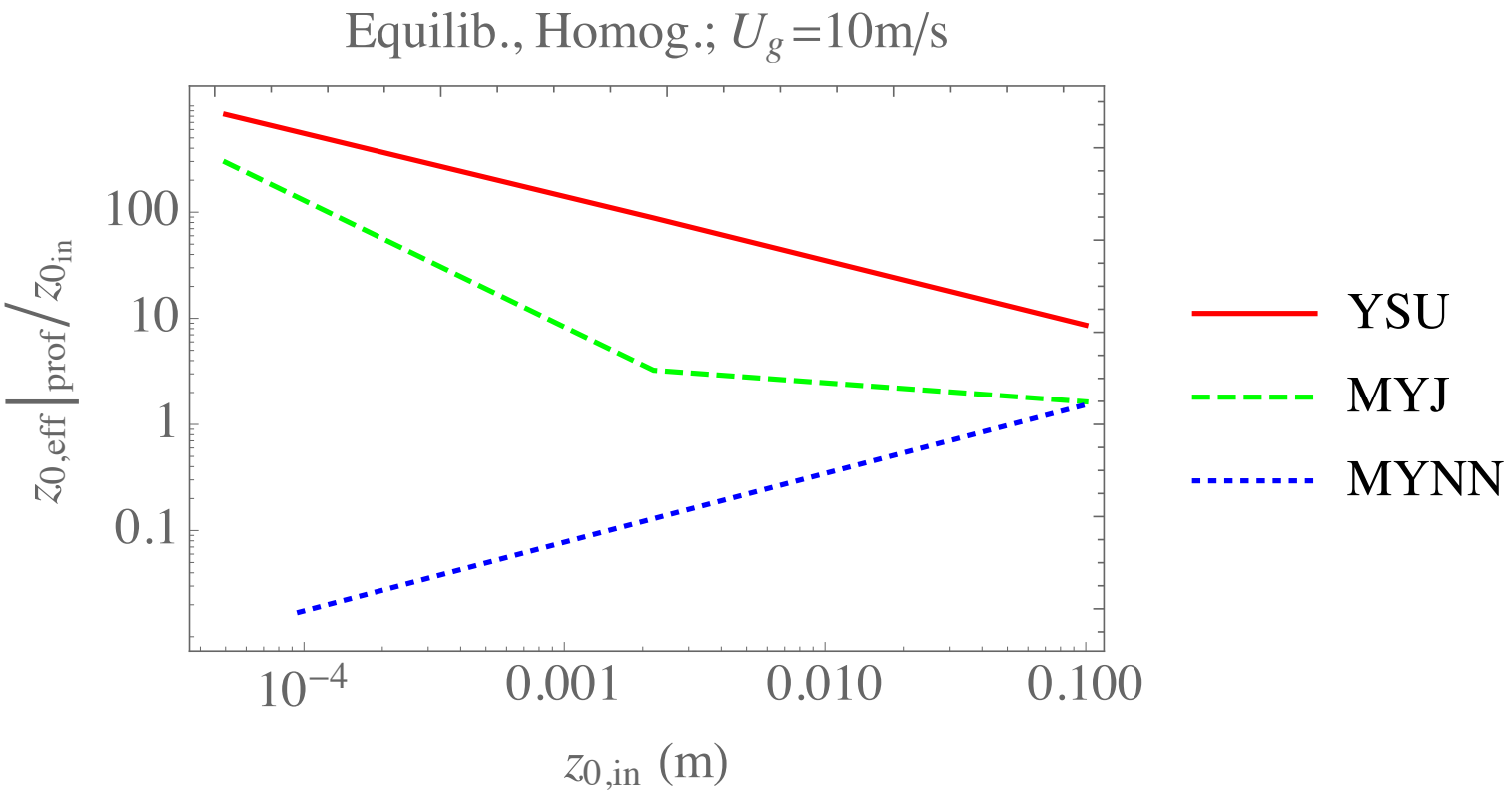
→ No resolution dependence



Equilibrium z_0-response : from wind profiles

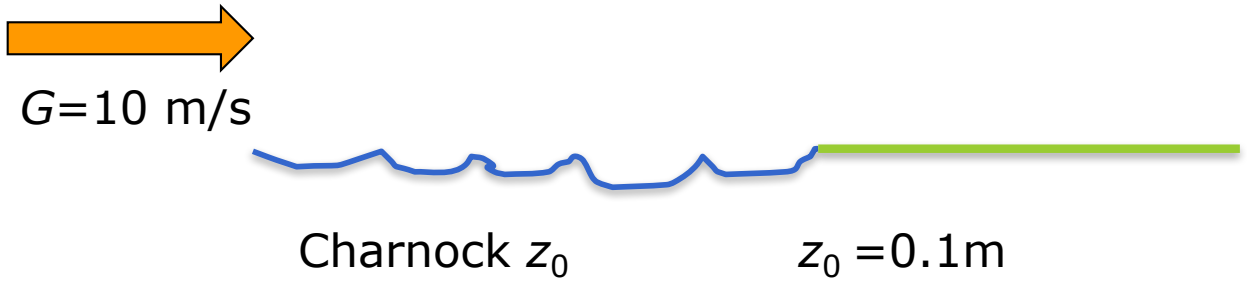
(homogeneous domains, G=10 m/s)

→ No resolution dependence

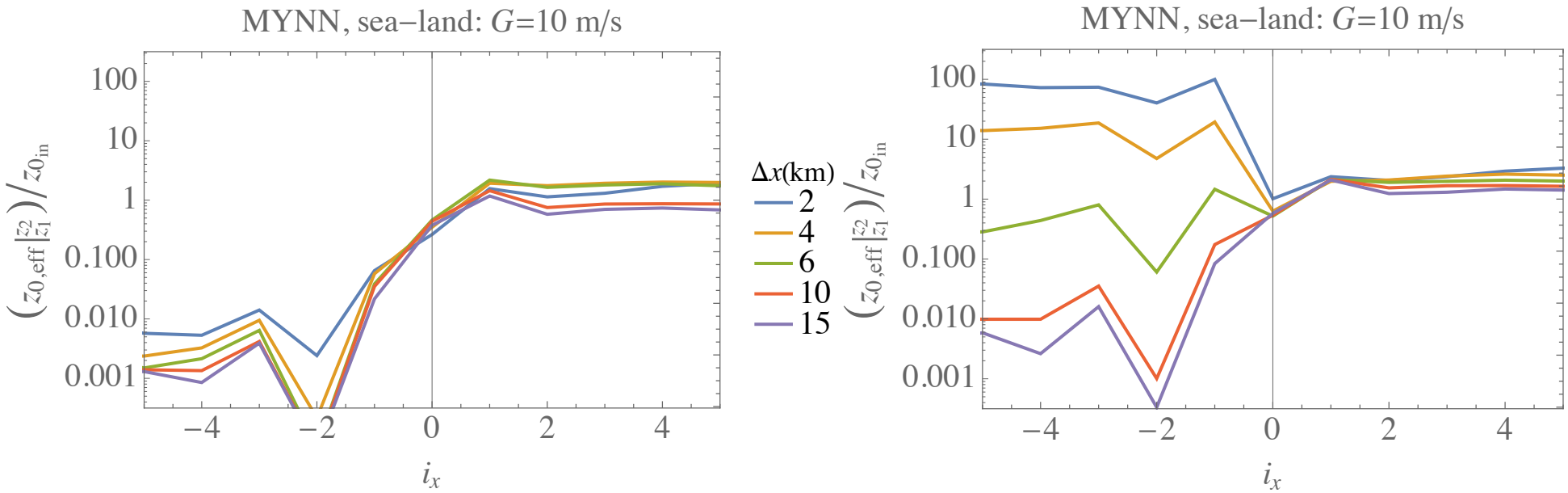


z_0 pseudo- / non-equilibrium via U_1, U_2

- Sea-to-land case



- Different response!
  - M-Y schemes: Resolution-dependence



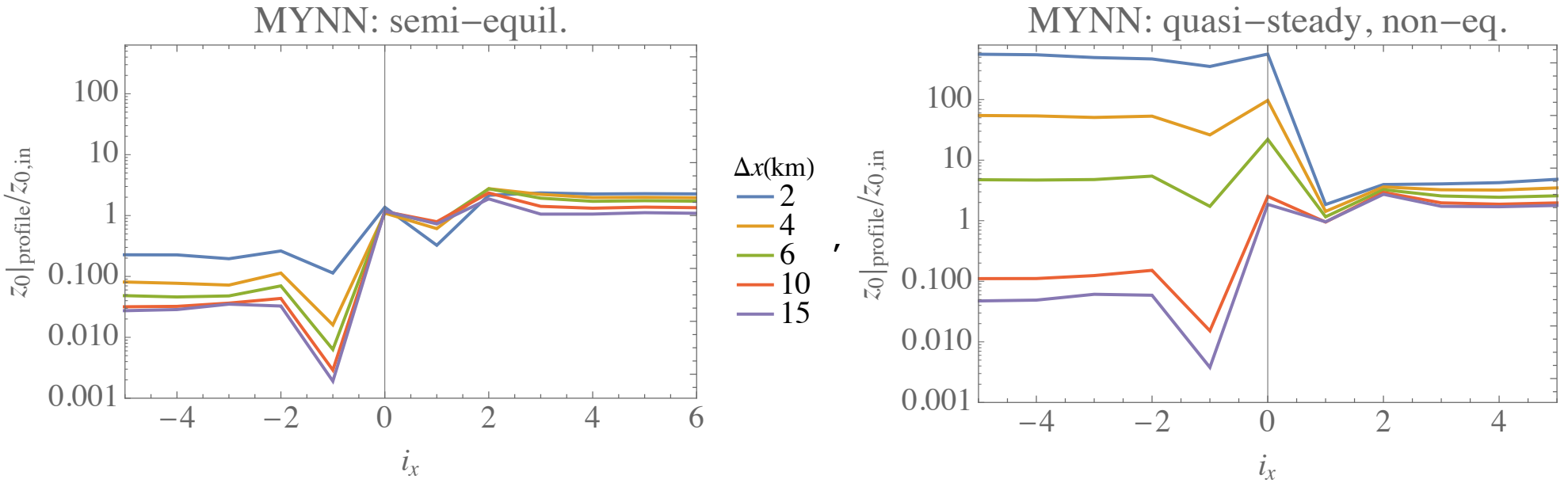
z_0 pseudo- / non-equilibrium via $U(z)$ profiles

- Sea-to-land case

G=10 m/s

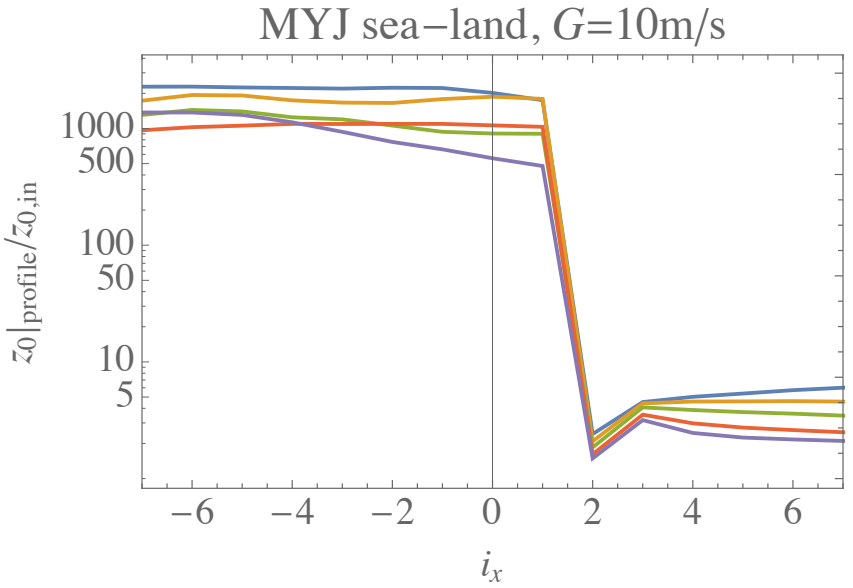
Charnock z_0 z_0 =0.1m

- M-Y schemes: Resolution-dependence

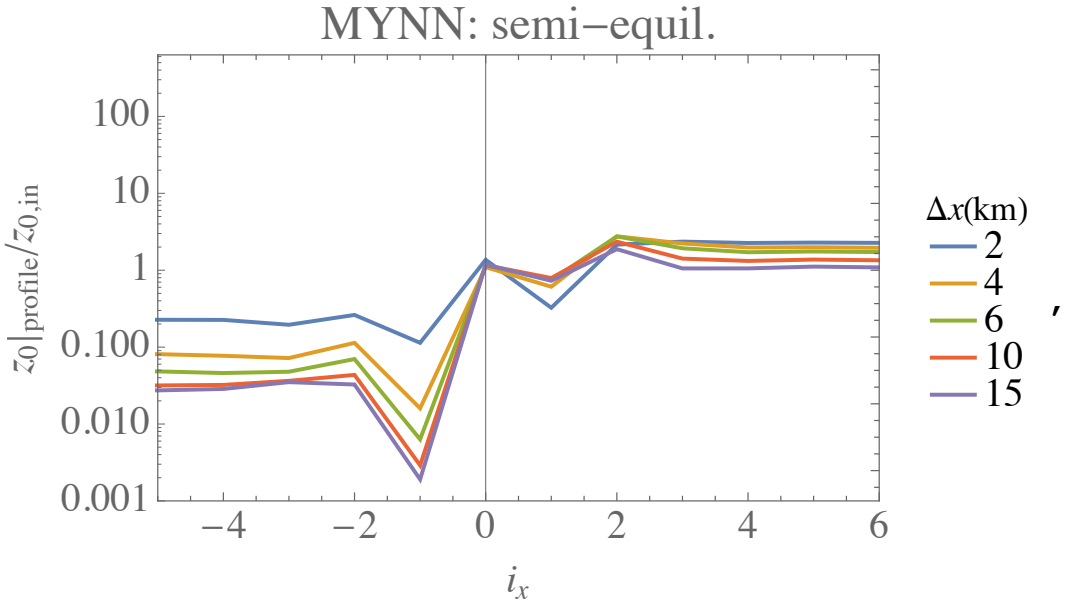


z_0 pseudo- / non-equilibrium via $U(z)$ profiles

- Sea-to-land case , G=10 m/s



- **M-Y schemes**:
  Resolution-dependence



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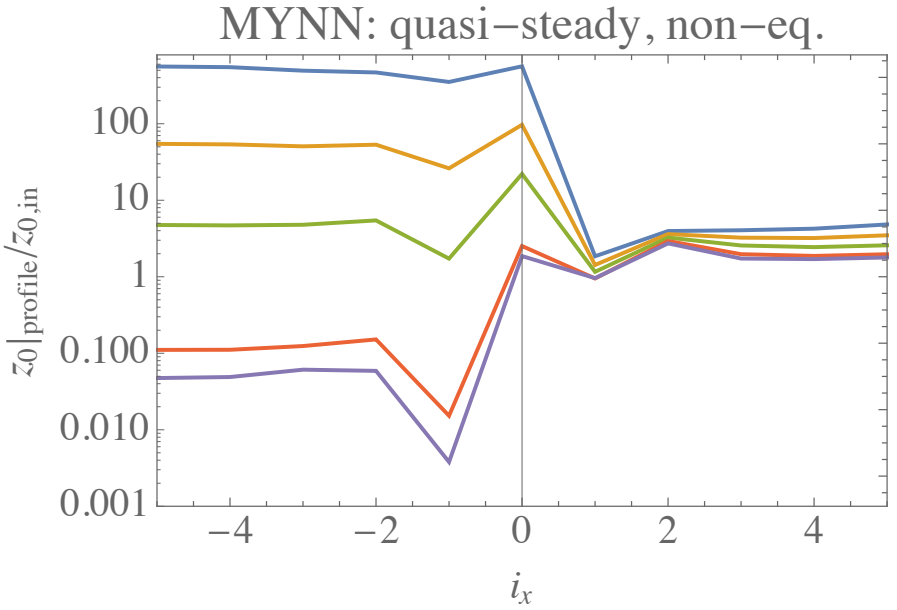
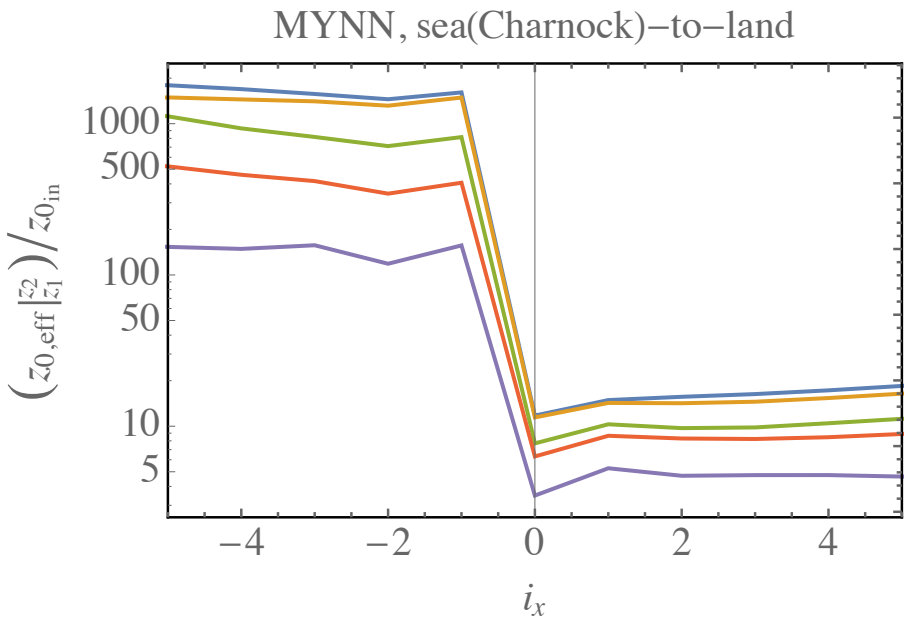


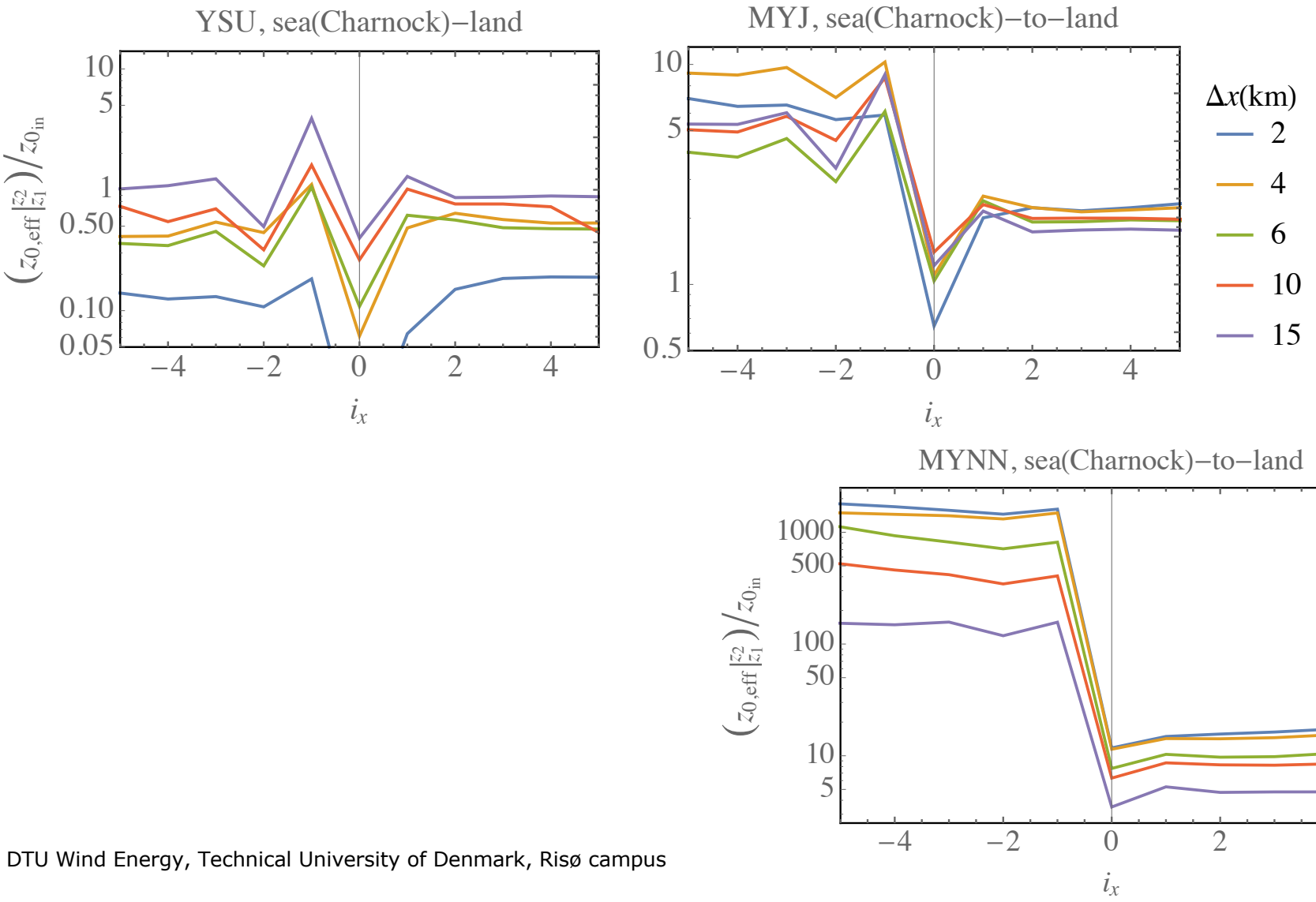
Non-equilibrium z_0-response via U_1, U_2

Sea-to-land now for nz=40 : vertical-resolution dependence



Non-equilibrium z_0-response via U_1, U_2

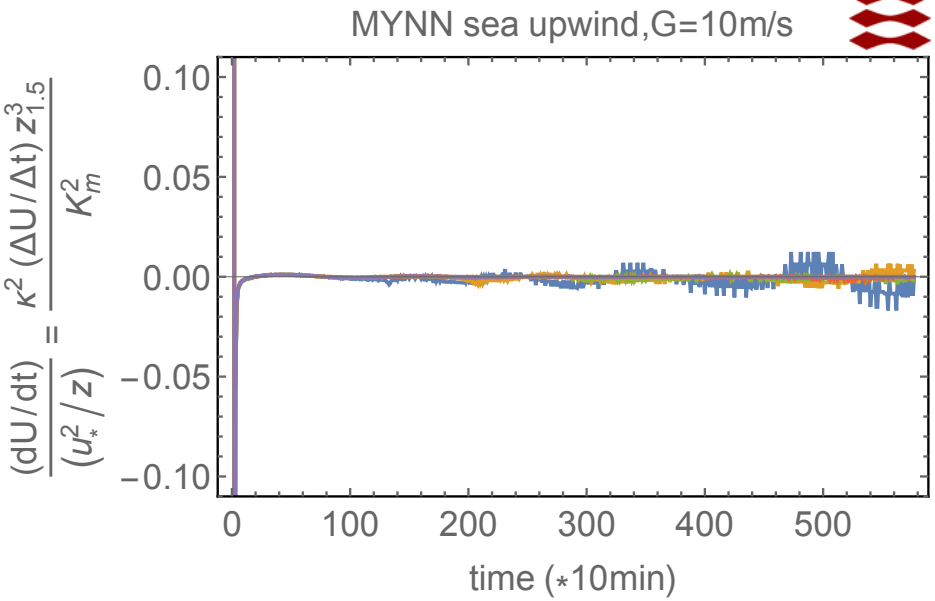
Sea-to-land now for nz=40 : vertical-resolution dependence



Can we really infer a z_0 ?

- Non-equilibrium, but quasi-steady:

$$\frac{dU}{dt} \ll \frac{u_*^2}{z}$$



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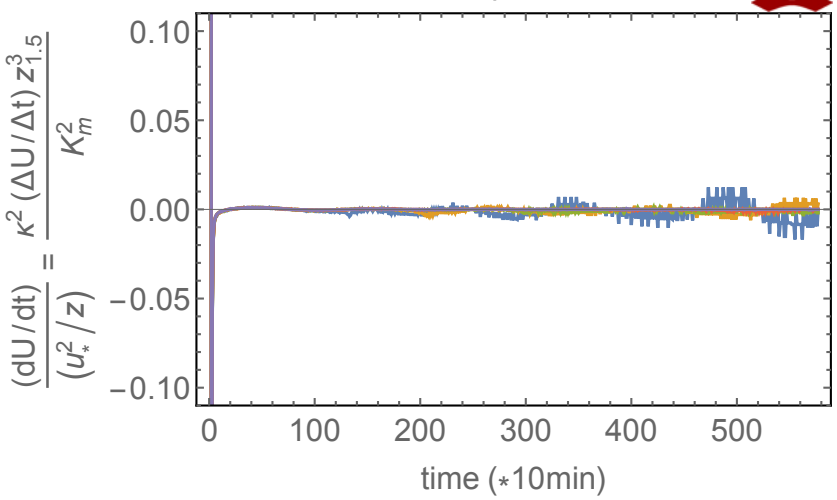
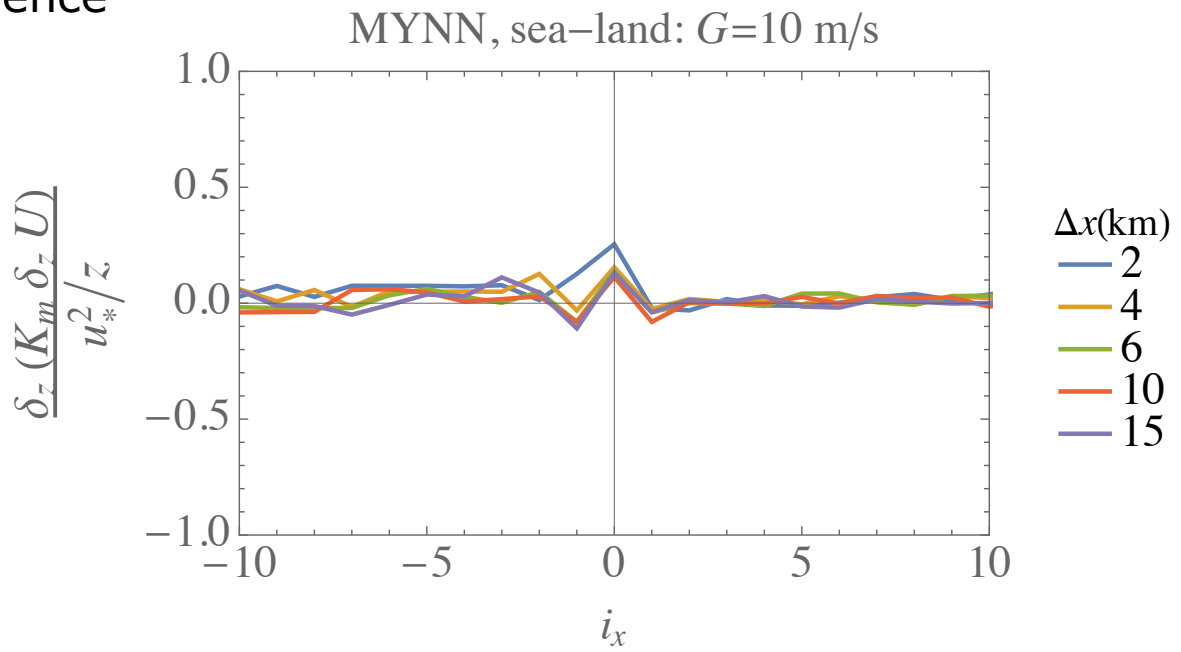


- Normalized stress-divergence

$$\frac{d\tau_{13}}{dz} \ll \frac{u_*^2}{z}$$



z_0 non-equilibrium : *U*-dependence

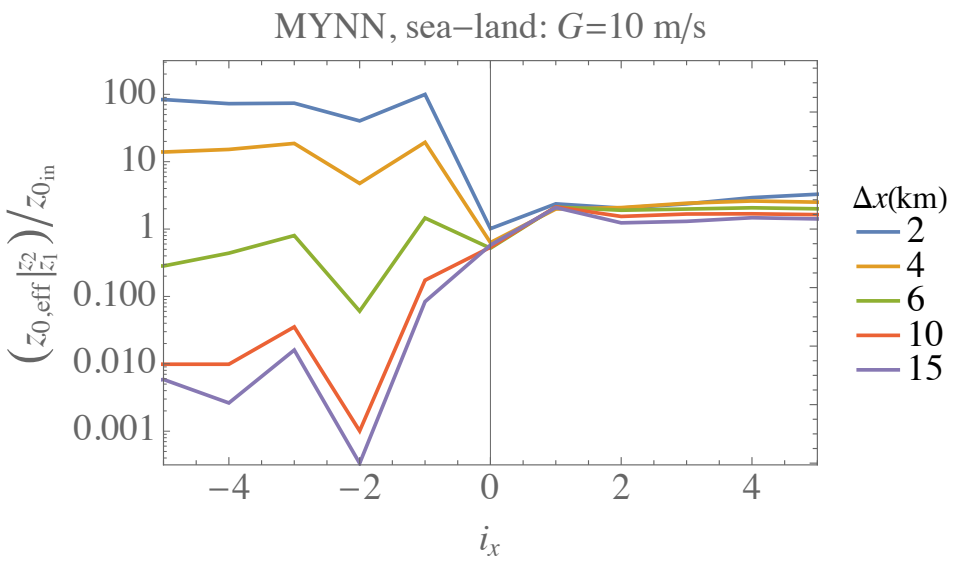
via $U(z)$ profiles

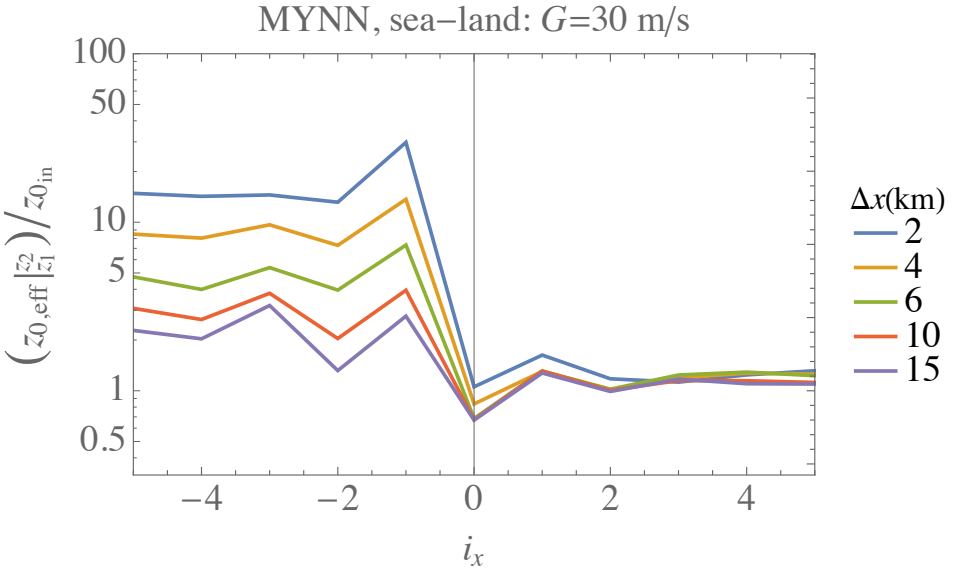
- Sea-to-land case

G={10,**30**} m/s

Charnock z_0 z_0 =0.1m

- Now speed and resolution-dependence





Non-equilibrium z_0-response : from profiles

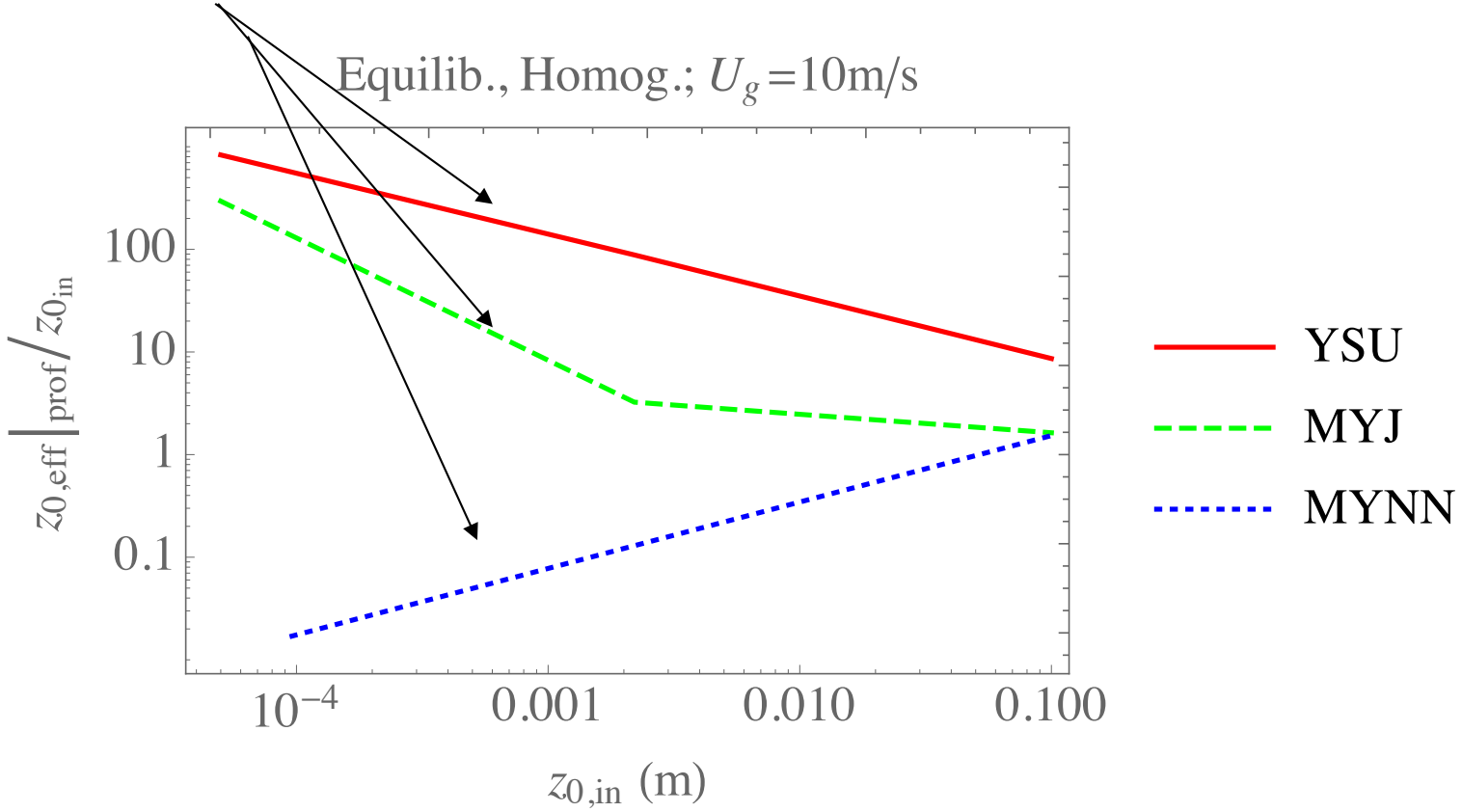
For higher wind speeds

→ Resolution dependence reappears

Compared to *equilibrium response*:

MYNN line moves upward

M-Y lines split, per resolution, as *U* increases

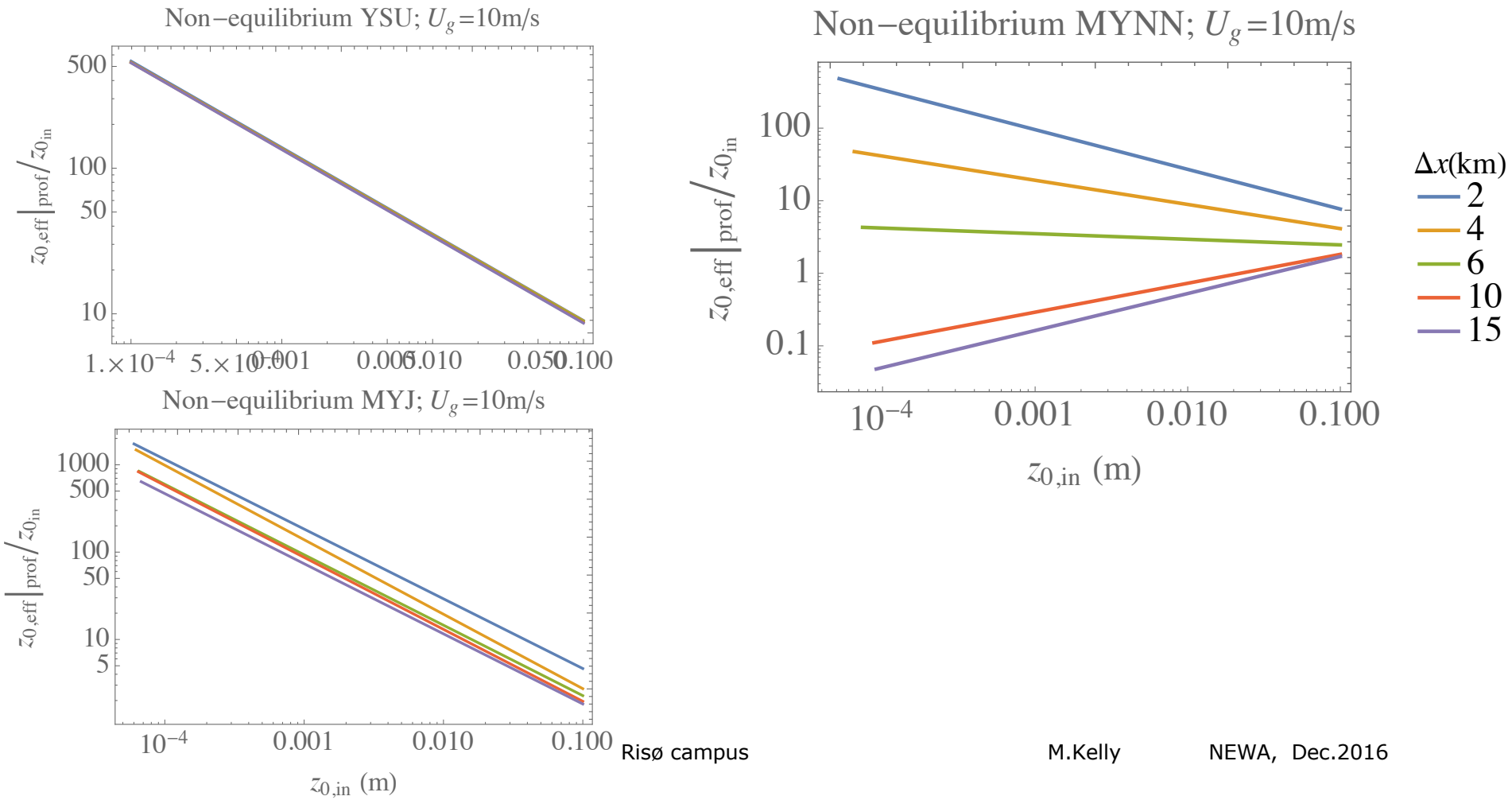


Non-equilibrium z_0-response : from profiles

For higher wind speeds

→ Resolution dependence reappears

MYNN line moves upward for fine resolutions
Each line here splits, per resolution, more as *U* increases



Summary

- Equilibrium response: no $z_{0,\mathrm{eff}}(\Delta x)$ –as expected
  - Differs per scheme
- Non-equilibrium response is different from equilibrium response
  - Δx -dependence (resolution, per scheme)
  - schemes appear tuned for some *nz*: Δz -dependence
  - Speed dependence appears for higher winds

- …further developments (in progress)
  - More complete z0-"mapping" (more $\{z_0, U\}$ regimes)
  - Geostrophic drag-law [GDL] parameter optimization

→ leads to (for NEWA/partners/products):
  - filtering z_0 maps for coasts per PBLs, Δx
  - Approximate scaling of wind speeds per z0 bias
  - Uncertainty estimate for generalization step